10

Vegetable Waste Compost Used as Substrate in Soilless Culture

Pilar Mazuela[1], Miguel Urrestarazu[2] and Elizabeth Bastias[1]
[1]*Universidad de Tarapacá*
[2]*Universidad de Almería*
[1]*Chile*
[2]*Spain*

1. Introduction

One of the main environmental impacts of forced systems in horticulture – such as plastic covers and soilless culture - is the generation of organic plant residues and substrate waste. For example, the surface area of greenhouse cultivated crops in the province of Almeria, in southeastern Spain, exceeds 30,000 ha. These generate approximately 1,000,000 tons of solid plant waste per year. Greenhouse industry residues cause serious environmental and visual pollution, making it necessary to look for new ways to eliminate these plant residues. This mass not only acts as a host for pests, microorganisms, rats and insects; it also has other harmful environmental effects such as pollution of the soil by toxic elements, effluent runoff, and the emission of bad smells. Conway (1996) indicated that an important factor for sustainable agriculture in areas using protected systems is the need to eliminate the harvest residues of these crops. Controlled composting appears to be an effective method of eliminating residues by recycling them. For example, Ozores-Hampton *et al.* (1999) reported that in Florida 1.5 million tons of compost could be produced per year.
The wastes generateed by intensive agriculture systems are very varied and frequently cannot be reused directly. Cara and Ribera (1998) indicated that greenhouses generate 29.1 tons of vegetable waste per ha and 6-10 tons of substrate remains per year in the province of Almería (Spain). A less indiscriminate form of management of these residues, however, could turn them into usable products. This would also reduce their environmental impact. Callejón et al., 2010 indicated that the assessment of the environmental impact of a potential waste treatment plants showed that it would be better to recycle and compost waste than to try to obtain energy from it through combustion. This compost can be used as a soil conditioner or to improve the structure in degraded soils or those with low organic matter content. Another alternative is to reuse these residues, incorporating them as ecologically friendly substrates in soilless cultivation in the form of compost.
Using waste materials, most of them locally produced, as soilless growing media has been the subject of an important number of studies, especially as an alternative to peat for ornamental potted plants (e.g., Ingelmo et al., 1997; Offord et al., 1998; Lao and Jiménez, 2004a,b), and less frequently for vegetable production (Shinohara et al., 1999; Ball et al., 2000) and even for tomato transplant production (Ozores-Hampton et al., 1999). However, it

has been suggested that certain types of compost alone are unsuitable as growing media due to unacceptably high salt and pH content (Spiers and Fietje, 2000), in particular when immature, unstable compost is used (Ozores-Hampton et al., 1999). Another disadvantage of the use of compost as substrate is that it is a very heterogeneous material and therefore needs to be amended so that it can be used as substrate (Urrestarazu et al., 2000; Urrestarazu et al., 2001; Urrestarazu et al., 2003; Sanchez-Monedero et al., 2004; Carrión et al., 2005; Mazuela et al., 2005; Mazuela et al., 2010)). Once physical-chemical properties were adjusted for soilless culture, yield trials proved the suitability of compost as an acceptable soilless growing media and as a viable and ecologically friendly alternative substrate.

Fig. 1. Leaching compost assays

Fig. 2. New and re-used compost from horticultural waste crops

Fig. 3. Texture and coarseness index in new compost

Fig. 4. Melon production using compost as substrate in southeastern Spain

2. Vegetable waste use as an alternative and friendly substrate

Many people are keen on the research and development of ecologically friendly substrates. Recently it has been demonstrated that these substrates are a perfectly viable alternative to other more traditional methods such as rockwool, perlite or hydroponic systems. However, in order to be competitive for vegetable production in the Mediterranean region, they must be used for at least one year. In recent years there has been an increase in soilless crop cultivation in southeast Spain (Almeria, Murcia and Granada) with a current surface area estimated at 5,000 ha, using substrates such as rockwool, perlite, sand, coconut fibre and other minor types (Urrestarazu and Salas, 2002).

Fig. 5. Cherry production using compost as substrate in northern Chile

Fig. 6. Tomato production using compost as substrate in greenhouse

Alternative substrates have the advantage of being locally produced, renewable and contaminant and disease-free (Salas et al., 2000), and may be less expensive than any other traditional growing media used in soilless crop production. Abad et al. (2002) reported that coconut coir waste may be used for ornamental crops, and the decision on whether to use it as a peat substitute will depend primarily on economic and technical factors, and secondly on environmental issues.

Fig. 7. Effect of high salinity on a tomato crop

Selected characteristics of some alternative substrates are given in Table 1.

	C[1]	AS[2]	CF[3]	PF[4]	RV[5]
Bulk density (g cm^{-3})	0.38	0.40	0.059	0.061	< 0.40
Real density (g cm^{-3})		1.40-1.45	1.51	1.46	1.45-2.65
Coarseness index (%)	62.2	84.2-86.3	34	97.5	
Total pore space (% vol)	80	71-72	96.1	95.8	> 85
Total water-holding capacity (mL L^{-1})	388	188-194	523	187	600-1000
Shrinkage (%)	11.1	10-12.3	14	10	<30
Organic matter content (% dry wt)	58.5	99	93.8	99	> 80
pH	7.8-8.0	5.1-5.2	5.71	5.76	5.2-6.3
Electrical conductivity (dS m^{-1})	22.2-34.3	2.44-2.70	3.52	0.63	0.75-1.99

Source: [1]Mazuela et al., 2005; [2]Urrestarazu et al. 2005a; [3]Abad et al., 1997 ; [4]Urrestarazu et al., 2006; [5]Abad et al., 1993

Table 1. Selected physical, physical-chemical and chemical properties of alternative substrates: compost (C), almond shells (AS), coir fiber (CF), pine fiber (PF) and reference value (RV)

Fig. 8. Melon transplant production

2.1 Plant pathogen elimination by composting

Many studies indicate that the elimination of plant pathogens is possible through composting, although for different time periods at different temperatures. High temperatures eliminate phytopathogens such as *Pythium irregulare*, *Pythium ultimun (*Suárez-Estrella et al., 2007), *Rhizoctonia solani* (Hoitink et al., 1976; Christensen et al., 2001; Suárez-Estrella et al., 2007), *Fusarium oxysporum f.sp. melonis* (Suárez-Estrella et al., 2003, 2004), *Xanthomonas campestris pv. Vesicatoria, Erwinia carotovora* and *Pseudomonas syringae pv. syringae* (Elorrieta et al., 2003; Suárez-Estrella et al., 2007), and several viruses such as tomato spotted wilt virus (TSWV) and pepper mild mottle virus (PMMV) (Suárez-Estrella et al., 2002). Suárez-Estrella et al. (2003) suggested that composting is therefore a useful method to recycle horticultural waste, when it is ensured that all pathogenic bacteria are eliminated in the process.

2.2 Trace metals

The levels of trace metals in different composts are known to be much higher than in most agricultural soils (He et al., 1992), and depend on the origin of the compost. Pinamonti et al. (1997) reported that the use of compost from sewage sludge and poplar bark did not cause any significant increase in heavy metal levels in soil or plants in the short/medium term; by contrast, their experiments clearly demonstrated that the compost from municipal solid waste increased concentrations of Zn, Cu, Ni, Pb and Cr in soil, and in the case of Pb and Cd also in the vegetation and the fruits. In Spain, as in other European countries such as The Netherlands and Italy, the concentrations of some heavy metals are regulated in order to guarantee the safe use of compost.

Heavy metal levels or potentially toxic microelements (Table 2) were below the tolerated limits in compost according to both the European (BOE, 1998) and American (US, 1997) regulations and the limits established by authors such as Abad et al. (1993) for soilless production of vegetables and ornamentals.

	Average contents in compost		Regulated limits			
Metal	USA[1]	Spain[2]	Vegetables[3]	Ornamentals[3]	Amendment[4]	USA[5]
Zn	503	95.9-179	1000	1500	1100	2800
Cu	154	37.2-98.5	100	500	450	1500
Cr	34.8	5.02-11.2	150	200	400	1200
Pb	215	6.18-9.1	600	1000	300	300
Ni	24.8	3.6-6.45	50	100	120	420
Co	-	1.29-2.07	50	50	-	-
Cd	2.9	0.11-0.25	5	5	10	39

Source: [1]Epstein et al., 1992; [2]Mazuela et al., 2005; [3]Abad et al.,1993; [4]BOE, 1998, [5]US Composting Council, 1997

Table 2. Concentrations of heavy metals (mg kg^{-1}) of compost obtained from horticultural crop residues in the United States and Spain and regulated limits

2.3 Leaching of horticultural greenhouse crop waste for substrate

Mazuela and Urrestarazu (2009) determined the effect of leaching of compost for substrate preparation with two composting processes; C1 compost formed by mixing pepper, bean and cucumber waste; and C2, compost formed by melon plant waste. In both cases, sawdust was added (1:4 ratio v/v), as a C/N relation conditioner. The composting process was described by Suárez-Estrella et al. (2003), who indicated that piles of 2 m^3 were turned over and aerated periodically after the first 14 days of composting. Electrical conductivity (EC), anion content (NO_3^-, $H_2PO_4^-$, SO_4^{2-}, Cl^-) and cations (Ca^{2+}, K^+, Mg^{2+}, Na^+) were determined by the saturation extract method (Warncke, 1986).

Table 3 shows EC values above 21.38 and 11.84, in compost C1 and C2, respectively, likeness ratio indicated by McLachlan et al., 2004; Sanchez-Monedero et al., 2004; Mazuela et al., 2005. These values are higher than the recommended range of 0.75-1.99 reported by Abad et al. (1993) as optimum for soilless culture (Table 1). Amendment with leaching 1:6 volumes is sufficient to produce acceptable values of EC for horticultural purposes (Sanchez-Monedero et al., 2004; Mazuela et al., 2005).

Soluble salts represent dissolved inorganic ions in the solution and are typically measured in terms of electrical conductivity. EC readings and mineral element concentrations of composts decreased sharply with leaching and eventually reached acceptable levels despite the high initial value of this parameter in the compost. This drop in the EC was parallel to that found in the concentrations of soluble mineral elements, mainly SO_4^{2-}, K^+, Cl^-, Mg^{2+}, Ca^{2+} and Na^+, and showed significant differences for higher levels of elements at the end of the experiment independent of the initial values in the composts. Often, soluble salt measurements from different studies or laboratories cannot be cross-referenced or there is a lot of confusion when comparing the results. Dimambro et al. (2007) and Carrión et al. (2005) reported that total salts were higher in mixed waste composts, predominantly due to high concentrations of K^+, Ca^{2+}, SO_4^{2-}, and Na^+. Nitrates and phosphates in leaching had low levels in both composts without significant differences. This suggests that the low levels of available nitrogen and the chemical binding or adsorption of phosphorus found in the composts studied will reduce N and P concentrations in leachates.

			Anions				Cations			
sv:wv		EC	NO_3^-	$H_2PO_4^-$	SO_4^{2-}	Cl^-	K^+	Na^+	Ca^{2+}	Mg^{2+}
1:1	C1	21.38	0.97	0.14	191.83	72.53	172.20	22.55	46.00	49.00
	C2	11.84	8.12	0.98	88.91	17.44	49.80	8.85	25.50	20.56
		**	ns	ns	*	**	*	*	**	*
1:2	C1	10.78	0.25	0.00	128.97	29.15	96.00	10.50	25.50	28.60
	C2	5.51	5.26	1.25	46.64	4.71	22.20	7.25	16.60	7.94
		*	ns	ns	**	**	**	**	ns	*
1:6	C1	2.66	1.96	0.09	23.01	2.51	16.60	1.62	5.83	3.95
	C2	1.95	0.63	0.38	23.92	0.54	6.10	0.76	10.40	3.39
		*	ns	ns	ns	*	*	*	*	ns
1:8	C1	1.59	0.54	0.07	4.59	0.43	3.14	0.46	2.06	1.19
	C2	0.82	0.08	0.21	19.94	0.03	2.66	0.38	9.53	2.89
		**	ns	ns	**	ns	ns	ns	**	**
1:10	C1	1.47	0.23	0.08	1.27	0.13	2.10	0.16	1.27	0.86
	C2	0.36	0.00	0.18	19.13	0.03	2.00	0.28	9.13	2.83
		**	ns	ns	**	ns	ns	ns	**	**

Values are means of three replicates.
*, **, ***, ns are $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$ and not significant or $P > 0.05$, respectively.
Source: Mazuela and Urrestarazu, 2009

Table 3. Electrical conductivity (dS m^{-1}), anion and cation contents (me L^{-1}) in leaching experiments of compost from two horticultural crop residue mixtures (C1, mixing pepper, bean and cucumber waste; C2, melon plant waste) using distilled water in different substrate volume: distilled water volume (sv:ws)

Thus to avoid environmental pollution, special emphasis must be paid to the management and treatment of effluents produced when leaching saline composts under commercial conditions. The preparatory operation needs about six times the water volume of the substrate and should be done inside a composting station, where the lixiviated fertigation is controlled. It is recommended to saturate the substrate with the standard nutrient solution before draining the bags (Villegas, 2004).

2.4 Characteristics of compost used as growing media and effects on yield and quality in horticultural crops

Physical properties are the most important characteristics in a new alternative substrate, because they do not change when the substrate is in the container. These characteristics determine the time and frequency of irrigation. Table 4 shows the particle-size distribution of composts and a coarseness index, expressed as the percentage weight of particles with Ø > 1 mm (Richards et al., 1986).

Particle Sizes (mm)								
<0.125	0.125-0.25	0.25-0.5	0.5-1	1-2	2-4	4-8	8-16	CI
2.59	6.00	11.88	17.36	36.31	18.14	5.14	2.58	62.2

Table 4. Texture and particle size distribution of compost originated from horticultural crop residues used as soilless growing media (% wt) and coarseness index (CI)

Texture was very similar to those recommended by Jensen and Collin (1985) for soilless vegetable culture. The coarseness index was about 62 %, similar to peat (63 %) and much higher than coconut coir waste (35 %) values reported by Noguera et al. (2000). hese values easily explain the high wettability of compost (Table 1) according to Bunt (1988). Bulk densities were within the limits of the optimal range. Total pore space showed lower than optimum levels. The total water-holding capacity of composts did not stay within the optimum values (Abad et al., 1993). Shrinkage, wettability and organic matter content stayed within the optimum range.
However, the deficient physical properties were not limiting for crop yield and quality (Table 5, Table 6) probably because crops were irrigated according to the physical analysis (Table 7) of the substrate, a method tailored to the water transport capabilities of each individual substrate (Drzal et al., 1999). The criteria of Smith (1987) and the necessary local adjustments (Salas and Urrestarazu, 2001) were adopted in the fertigation management.

	Tomato				Melon (Galia)			
	cv Josefina[1]		cv Daniela[2]		cv Yucatán[3]		cv Danubio[4]	
Substrate	kg m^{-2}	n° m^{-2}	kg m^{-2}	n° m^{-2}	kg m^{-2}	n° m^{-2}	kg m^{-2}	n° m^{-2}
CW	6.82	790	4.68	43	6.55	4.97	5.89	5.11
C	6.00	712	4.75	44	6.05	4.80	5.29	4.63

Source: [1]Urrestarazu et al., 2000; [2]Urrestarazu et al., 2003; [3]Mazuela et al., 2005; [4]Mazuela and Urrestarazu, 2009

Table 5. Effect of coconut coir waste (CW) and compost (C) on yield of melon crops.

	Yucatán[1]				Danubio[2]			
	F	TSS	pH	DWC	F	TSS	pH	DWC
CW	1.71	12.35	6.26	9.47	2.15	10.45	6.92	7.94
C	1.56	12.66	6.22	9.61	1.81	10.50	6.67	8.12

Source: [1]Mazuela et al., 2005; [2]Mazuela and Urrestarazu, 2009

Table 6. Effect of coconut coir waste (CW) and compost (C) on selected fruit parameters of melon crops.

	Yucatán[1]				Danubio[2]			
	Drainage			Uptake	Drainage			Uptake
	EC	pH	%	L m^{-2} $crop^{-1}$	EC	pH	%	L m^{-2} $crop^{-1}$
CW	4.76	5.71	21.41	2852	3.11	6.52	18.39	2049
C	4.00	7.02	31.72	2433	3.67	7.37	22.63	1943
P	ns	ns	ns	ns	ns	ns	ns	ns

EC: Electric conductivity (dS m^{-1})
Source: [1]Mazuela et al., 2005; [2]Mazuela and Urrestarazu, 2009

Table 7. Daily mean fertigation parameters and water uptake of melon crops in coconut coir waste (CW) and compost (C)

As part of a correct management procedure, previous acid rinsing and saturation with the standard nutrient solution are recommended in order to reduce the compost salinity and inadequate pH of the rhizosphere environment (Table 3). Once the physical-chemical properties were adjusted for soilless culture, yield trials proved the suitability of the compost as an acceptable soilless growing media and as a viable and ecologically-friendly alternative to rockwool and coconut coir waste (Table 8). In northern of Chile, Mazuela eta al., (2010) have similar results that shows in Table 9.

Fig. 9. Vegetable waste compost produced with grapes residues from CAPEL, Punitaqui, Chile

	Yield			Quality	
Substrate	kg m^{-2}	n^{o} fruit m^{-2}	F (kg)	TSS (^{o} Brix)	DWC (%)
Compost	6.05	4.80	1.6	12.7	9.6
Almond shells	6.52	4.56	2.2	12.5	9.8
Coir fiber	6.55	5.08	1.7	12.3	10.1
Pine fiber	6.19	5.12	1.6	11.8	9.9
Rockwool	6.57	5.00	1.7	11.8	7.4

F: Firmness; TSS: Total Soluble Solids; DWC: Dry Water Content
Source: Urrestarazu et al., 2006

Table 8. Yield and quality in melon crops of alternative substrates: compost, almond shells, coir fiber, pine fiber and rockwool

	Fertigation			Yield		Quality		
	EC	pH	%	kg m^{-2}	n° m^{-2}	TSS	FF	DWC
GH	2.86	7.51	20.59	3.79	342	8.43	1.11	8.47
AM	3.05	7.55	22.97	2.93	293	9.20	1.14	9.67

EC: Electric conductivity (dS m^{-1}); TSS: Total soluble solids (^{o} Brix); FF: Firmness (kg); DWC: Dry weight content (%)

Table 9. Fertigation in drainage parameters, yield and quality in tomato (cherry) crop, in northern of Chile in Greenhouse (GH) and antiaphid mesh (AM)

2.5 Re-used substrate from waste materials

Recently, it has been demonstrated that the use of some ecologically friendly substrates are perfectly viable as alternatives to other more traditional media such as rockwool, perlite or hydroponic systems. Almond shell was found to be a viable culture substrate by Lao and Jiménez (2004a, b); these researchers used it as a peat substitute for an ornamental crop. Urrestarazu. (2008) reported that pure compost can be an acceptable substitute growing media for rockwool and coconut coir waste once it is leached and adjusted to physical-chemical proprieties. o limiting factors in comparison to rockwool were found for tomato and melon crops when alternative substrates were used as growing media.

Rockwool slab, perlite and coconut bag culture are used in southeastern Spain for two or three years for vegetable production (García, 2004; Villegas, 2004); consequently, in order to be competitive in the market of soilless crops and to have similar commercial opportunity, the unit with an alternative substrate must be usable for this time. Urrestarazu et al. (2008) showed that re-used alternatives substrates as compost or almond shells did not affect yield in melon and tomato crops (Table 10). Because environmental care and economic profit to the grower are of paramount importance, it was important to see if this re-use of alternative substrate would be viable in Mediterranean conditions.

Substrate	Melon Galia (cv Aitana)		Tomate (cv Pitenza)	
	kg m^{-2}	n° fruits m^{-2}	kg m^{-2}	n° fruits m^{-2}
New compost	5.1	4.5	7.7	99
Re-used compost	5.2	5.0	7.8	99

Source: Urrestarazu et al., 2008

Table 10. Yield of melon and tomato crops with new and reused compost

Fig. 10. Pepper seeds production in Quillota, Chile

Bulk density is a relevant substrate physical propriety, because this allows easier transportation of crop units in the greenhouse industry (Abad et al., 2004). The new substrates, before reutilization, were within the limit of optimal range (Urrestarazu et al., 2005b); in fact, this is the major disadvantage for transport in comparison to other more popular substrates such as rockwool and perlite (Mazuela et al., 2005; Urrestarazu et al., 2005b).

2.6 Fertigation management and reference values for nutrient dissolution in organic substrates

Part of a correct management procedure for the use of compost as substrate in growing media is to saturate the bags with nutrient solution before draining the containers, in order to reduce the compost salinity in the rhizosphere environment. Once the electrical conductivity level was adjusted for soilless culture, yield trials proved the suitability of compost as an acceptable growing medim and this ecologically friendly alternative did not affect production, yield or fruit quality of melon and tomato crops. Thus the use of compost in soilless culture is a viable alternative to resolve the environmental problem of vegetable waste.

In the Mediterranean region, the control of soilless vegetable cultivation is commonly through measurement of some fertigation parameter ranges in the drainage; pH, electrical conductivity and volume percentage (e.g., Villegas, 2004; García, 2004; Urrestarazu et al., 2005b). Table 11 shows reference values of nutrient dissolution for horticultural crops for each substrate. They are measured almost daily and are easier and cheaper than other analyses or/and fertigation methods based on nutrient solution content in the substrate (Sonneveld and Straver, 1994), which in practice are only used one or two times during the crop cycle. Smith (1987) and Urrestarazu et al. (2005a, 2008) suggested that under adjusted management of the fertigation according to the different proprieties of the substrate, and within certain limits, it is possible to maintain the main parameters used as control for the fertigation method. Since in southeastern Spain rockwool (García, 2004) and perlite (García et al., 1997) are commonly used for similar lengths of time, it is suggested that alternative substrates are economically viable, since their cost is the same.

Fig. 11. Pepper production in growing media in southeastern Spain

Crop	Substrate	mmol L^{-1}						
		NO_3^-	$H_2PO_4^-$	SO_4^{2-}	NH_4^+	K^+	Ca^{2+}	Mg^{2+}
Tomato	Rockwool[1]	10,5	1,5	2,5	0,5	7,0	3,75	1,0
	Perlite[2]	12,5	2,0	1,75		5,0	5,0	1,8
	Organic[3]	13,0	1,75	1,25	1,0	7,5	4,0	1,25
Pepper	Rockwool[4]	15,5	1,25	1,75	1,25	6,5	4,75	1,5
	Perlite[5]	13,5	1,5	1,35		5,5	4,5	1,5
	Organic[3]	13,0	2,0	2,0	1,0	6,0	4,25	2,0
Melon	Organic[3]	13,0	2,3	2,2	1,0	7,0	4,25	2,2
Cucumber	Rockwool[4]	16,0	1,25	1,375	1,25	8,0	4,0	1,375
	Organic[3]	15,0	1,75	1,25	1,0	7,75	4,00	1,25
Green Beans	Rockwool[4]	12,5	1,25	1,125	1,0	5,5	3,25	1,25
	Perlite[2]	13,5	1,75	1,65		6,0	3,25	1,75

Source: [1]Sonneveld, 1980; [2]García and Urrestarazu, 1999; [3]Urrestarazu and Mazuela, 2005: [4]Sonneveld and Straver, 1994; [5]Escobar, 1993

Table 11. Reference values for nutrient dissolution in rockwool, perlite and alternative (organic) substrates.

Fig. 12. Composting in arids zones, Arica, Chile

Fig. 13. Blueberry production in Arequipa, Peru

Fig. 14. Desert lands can be cultivates by soilless culture

3. Conclusion

Once of the main environmental impacts of forced systems in horticulture -such as plastic covered and soilless culture- is the generation of organic plant residues and substrate waste. Many people are keen on research and development of ecologically friendly substrates. The suitability of compost from horticultural residues as a growing medium in vegetable crop production is an acceptable substitute for rock wool and coconut coir waste. The unit of soilless crop: rockwool slab, perlite and coconut bag culture are used in South eastern Spain between two or three years by vegetable production, consequently in order to be competitive in the market of soilless crops and to have similar commercial opportunity the unit with the alternative substrate must be used during this time. Because the environmental care and economic profit to grower is of paramount importance, it was important to see if this reuse of alternative substrate would be viable in Mediterranean conditions.. Part of a correct management procedure for the use of compost as substrate in growing media is to saturate the bags with nutrient solution before draining the containers in order to reduce the compost salinity in the rhizosphere environment. Once the electrical conductivity level was adjusted for soilless culture, yield trials proved the suitability of the compost as an acceptable growing media and this ecologically friendly alternative does not affect production, yield and fruit quality of horticultural crops. In conclusion, the use of compost in soilless culture is a viable alternative to resolve the environmental problem of vegetable waste.

4. Acknowledgement

This work was financially supported by project FEDER AGL2010-18391 (Spain), proyect UTA 9720-10 and Convenio de Desempeño UTA-MECESUP2 (Arica Chile).

5. References

Abad, M., Martínez, P.F., Martínez, M.D. & Martínez, J.(1993). Evaluación agronómica de los sustratos de cultivo. *Actas de horticultura* 11, 141-154.

Abad, M.; Noguera, P. & Carrión, C. (2004). Los sustratos en los cultivos sin suelo. In: M., Urrestarazu (Eds.), *Manual del cultivo sin suelo*. Servicio de Publicaciones Universidad de Almería. Mundi-Prensa, Madrid, pp. 113-158.Abad, M.; Noguera, P.; Noguera, V.; Roig, A.; Cegarra, J. & Paredes, C. (1997). Reciclado de residuos orgánicos y su aprovechamiento como sustratos de cultivo. *Actas de Horticultura,* 19: 92-109.

Abad, M., Noguera, P., Puchades, R., Maqueira, A. & Noguera, V. (2002). Physico-chemical and chemical properties of some coconut coir dusts for use as a peat substitute for containerised ornamental plants. *Biores. Technol.*, 82:241-245.

Ball, A.S.; Shah, D. & Wheatley, C.F. (2000). Assessment of the potential of a novel newspaper/horse manure-based compost. *Biores. Technol.*, *73*, 163-167.

Bunt, A.C. (1988). Media and mixes for container-grown plants, 2nd ed. Unwin Hyman Ltd., London. 309 pp.

BOE. (1998). Boletín Oficial del Estado. num. 131, Spain.

Callejón A.J.; Carreño A.; Sánchez-Hermosilla J. & Pérez J. (2010). Evaluación de impacto ambiental de centro de transformación y gestión de residuos sólidos agrícolas en la provincia de Almería (España). *Informes de la Construcción*, 62 (518): 79-93.

Cara, G. & Ribera, J. (1998). Residuos en la agricultura intensiva. El caso de Almería. *Encuentro medioambiental Almeriense: En busca de soluciones.* Almería, Spain. March 7-8. pp. 128-132.

Carrión, C., Abad, M., Maquieira, A., Puchades, R., Fornes, F. & Noguera, V. (2005). Leaching of composts from agricultural wastes to prepare nursery potting media. *Acta Hort.* (ISHS) 697:117-124

Christensen, K.K., Kron, E. & Carlsbaek, M., (2001). Development of a Nordic system for evaluating the sanitary quality of compost. Nordic Council of Ministers, Copenhagen.

Conway, K.E. (1996) An overview of the influence of sustainable agricultural system on plant diseases. *Crop protection*, *15*, 223-228.

Dimanmbro, M.E.; Lillywhite, R.D. & Ranh, C.R. (2007). *Compost Sci. Util.*, 15(4): 243-252

Drzal, M.S., Fonteno, W.C. & Cassel, D.K. (1999). Pore fraction analysis. A new tool for substrate testing. *Acta Hort.*, *481*, 43-53.

Elorrieta, M.A., Suárez-Estrella, F., López, M.J., Vargas-García, M.C. & Moreno, J. (2003). Survival of phytopathogenic bacteria during waste composting. *Agriculture, Ecosystems and Environment* 96, 141–146.Epstein, E.; Chanay, R.L.; Henry, C. & Logan, T.J. (1992). Trace elements in municipal solid waste compost. *Biomass Bioenergy*, *3* (3-4), 227-238.

Epstein, E.; Chanay, R.L.; Henry, C. & Logan, T.J. (1992). Trace elements in municipal solid waste compost. *Biomass Bioenergy*, *3* (3-4), 227-238.

Escobar, I. (1993). Cultivo del pimiento en sustratos en las condiciones del sudeste español. En: E. Martínez y M. García (ed). *Cultivo sin suelo: hortalizas en clima mediterráneo.* Ediciones de Horticultura, Reus, Spain, pp.109-113.

García, A. (2004). Cultivo en lana de roca II. In: Tratado de cultivo sin suelo, 3rd Ed., ed. M. Urrestarazu, Mundi-Prensa, Madrid, pp. 622-636.

García, M. & Urrestarazu, M. (1999). Recirculación de la disolución nutritiva en los invernaderos de la Europa del Sur. Caja Rural de Granada. 171 p.García, A. 2004. Cultivo en lana de roca II. In: Tratado de cultivo sin suelo, 3rd Ed., ed. M. Urrestarazu, Mundi-Prensa, Madrid, pp. 622-636.

García, M., Guzmán, M., Urrestarazu, M., Salas, M.C. & Escobar, I. (1997). Evaluación de diferentes parámetros en cultivo de perlita para distintas especies hortícolas en invernadero. *Actas de Horticultura* 19, 519-525.

Jensen, M.H. & Collin, W.L. (1985). Hydroponic vegetable production. In *Horticultural Review*; Janick, J., Ed.,. The AVI Publishing Co: Westport, CT, USA, 7, 483-558.

He, X.; Traina S.J. & Logan, T.J. (1992). Chemical properties of municipal solid waste composts. *J. Environ. Qual.*, *21*, 318-329.

Hoitink, H.A.J., Herr, L.J. & Schmitthenner, A.F., (1976). Survival of some plant pathogens during composting of hardwood tree bark. *Phytopathology* 66, 1369–1372.

Ingelmo, F., Canet, R., Ibañez, M.A., Pomares, F. & García, J. (1997). Use of MSW compost, driede sewage sludge an other wastes as partial substitutes for peat and soil. *Commun. Soil Sci. Plant Anal*., 27:1859-1874.

Lao, M.T. & Jiménez, S. (2004)a. Evaluation of almond shell as a culture substrate for ornamental plants. I. Characterisation. Øyton. *International Journal of Experimental Botany* 53, 69-78.

Lao, M.T. & Jiménez, S. (2004)b. Evaluation of almond shell as a culture substrate for ornamental plants. II. *Ficus benjamina*. Øyton. *International Journal of Experimental Botany* 53, 79-84.Mazuela, P; Acuña, L; Alvàrez, M. & Fuentes, A. (2010). Producción y calidad de un tomate cherry en dos tipos de invernadero en cultivo sin suelo. *Idesia,* 28(2):97-100

Mazuela, P., Salas, M.C. & Urrestarazu, M. (2005). Vegetable waste compost as substrate for melon. *Commun. Soil Sci. Plant Anal*., 36 (11-12): 1557-1572.Mazuela, P. & M. Urrestarazu. 2009. The Effect of Amendment of Vegetable Waste Compost Used as Substrate in Soilless Culture on Yield and Quality of Melon Crops. *Compost Science & Utilization* 17:103-107.

Mazuela, P.; Urrestarazu, M.; Salas, M.C. & Guillén, C. (2004). Comparison between different fertigation parameters and yield using pure compost and coir waste fibre in tomato (*Lycopersicon esculentum* cv Pitenza) crop by soilless culture. *Acta Horticulturae*, 659: 653-656.

McLachlan, K.L., Chong, C., Voroney, R.P., Liu, H.W. & Holbein, B.E. (2004). *Commun. Soil Sci. Plant Anal.*,, 12(2): 180-184

Noguera, P.; Abad, M.; Noguera, V.;. Puchades, R. & Maquieira, A. (2000). Coconut coir waste, a new and viable ecologically friendly peat substitute. *Acta Hort., 517*, 279-286.

Offord, C.A., Muir, S. & Tyler, J.L. (1998). Growth of selected Australian plants in soilles media using coir as a substitute for peat. *Aust. J. Exp. Agric*., 38:879-887.

Ozores-Hampton, M., Vavrina, C.S. & Obreza, T.A. 1999. Yard Trimmin-biosolids Compost: Possible Alternative to Spahgnum Peat Moss in Tomato Transplant Production. *Commun. Soil Sci. Plant Anal*., 7:42-49.

Pinamonti, F.; Stringari, G.; Gasperi, F. & Zorzi, G. (1997) The use of compost: its effects on heavy metal levels in soil and plants. Resouces, *Conservation and Recycling*, *21*, 129-143.

Richards, D.; Lane, M. & Beardsell, D.V. (1986). The influence of particle-size distribution in pinebark:sand:brown coal potting mixes on water supply, aeration and plant growth. *Scientia Hort*., *29*, 1-14.

Salas, M.C. & Urrestarazu, M. (2001). *Técnicas de fertirrigación en cultivo sin suelo*, Manuales de la Universidad de Almería, Servicios de Publicaciones de la Universidad de Almería, Spain. 280 pp.

Salas, M.C.; Urrestarazu, M.; Moreno, J. & Elorrieta, M.A. 2000. Sustrato alternativo para su uso en cultivo sin suelo. *Phytoma* 123, 52-55.

Sánchez-Monedero, M.A., Roig, A., Cegarra, J., Bernal, M.P., Noguera, P.; Abad, M. & Antón, A. (2004). *Commun. Soil Sci. Plant Anal.*, 12(2): 161-168

Shinohara, Y.; Hata, T.; Mauro, T.; Hohjo, M. & Ito, T. (1999). Chemical and physical properties of the coconut-fiber substrate and the growth and productivity of tomato (*Lycopersicon esculentum* Mill) plants. *Acta Hort.*, *481*, 145-149.

Smith, D.L. (1987). Rockwool in Horticulture. Grower Book: London. 153 pp.

Sonneveld, C. (1980). Growing cucumbers and tomatoes in Rockwool. Proceedings national congress on soilless culture. Wageningen, pp. 253-262

Sonneveld, C., & Straver, N. (1994). Nutrient Solutions for Vegetables and Flower Grow in Water or Substrates. Naaldiwijk, The Netherlands: Proefstation voor tuinbouw onder glas te Naaldiwjk.

Spiers, T.M. & Fietje, G. (2000). Green Waste Compost as a Component in Soilless Growing Media. *Compost Sci. Util.*, *8* (1), 19-23.

Suárez-Estrella, F., López, M.J., Elorrieta, M.A., Vargas-García, M.C. & Moreno, J., (2002). Survival of phytopathogen viruses during semipilot-scale composting. In: Insam, H., Riddech, N., Klammer, S. (Eds.), *Microbiology of Composting*. Springer-Verlag, Berlín, pp. 539–548.

Suárez-Estrella, F., Vargas-García, M.C., Elorrieta, M.A., López, M.J. & Moreno, J. (2003). Temperature effect on *Fusarium oxysporum* f.sp. *melonis* survival during horticultural waste composting. *J. Applied Microbiology* 94, 475–482.

Suárez-Estrella, F., Vargas-Garrcía, M.C., López, M.J. & Moreno, J. (2007). Effect of horticultural waste composting on infected plant residues with pathogenic bacteria and fungi: Integrated and localized sanitation. *Waste Management* 27, 886-892

Suárez-Estrella, F., Vargas-Garrcía, M.C., López, M.J. & Moreno, J., (2004). Survival of Fusarium oxysporum f.sp. melonis on plant waste. *Crop Protection* 23, 127–133.

Urrestarazu, M. & Mazuela, P. (2005). Introducción al manejo del fertirriego en cultivo sin suelo. Riegos y Drenajes XXI, 141:34-40.

Urrestarazu, M., Martínez, G.A., & Salas, M.C., (2005). Almond shell waste: possible local rockwool substitute in soilless crop culture. *Scientia Hort.,* 103, 453-460.

Urrestarazu, M., Mazuela, P. & Alarcón, A.L. (2006). Cultivo en sustratos alternativos. p 147-173. IN: A.L. Alarcón (ed.). *Cultivos sin suelo*. Ediciones de Horticultura, Reus, España

Urrestarazu, M., Mazuela, P., Del Castillo, J., Sabada, S. & Muro, J. 2005. Fibra de pino: un sustrato ecológico. *Horticultura Internacional*, 49: 28-33.

Urrestarazu, M., Mazuela, P.C. & Martínez, G.A. (2008). Effect of substrate reutilization on yield and properties of melon and tomato crops. *J. Plant Nutrition* 31, 2031-2043

Urrestarazu, M. & Salas, M.C. (2002). El papel de los cultivos sin suelo en la moderna agronomía. *Vida Rural*, 145:54-58.

Urrestarazu, M., Salas, M.C. & Mazuela, P. (2003). Methods of correction of vegetable waste compost used as substrate by soilless culture. *Act. Hort.* 609, 229-233.

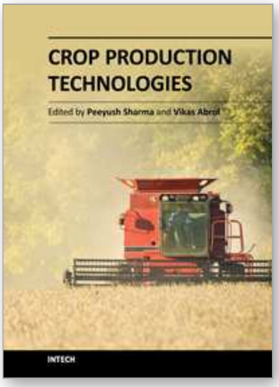
Urrestarazu, M., Salas, M.C., Padilla, M.I., Moreno, J., Elorrieta, M.A., Carrasco, G. (2001). Evaluation of different composts from horticultural crop residues and their uses in greenhouse soilless cropping. *Acta Hort*. 549, 147-152.

Urrestarazu, M.; Salas, M.C.; Rodríguez, R.; Elorrieta, M.A. & Moreno, J. (2000). Evaluación agronómica del uso del compost de residuos hortícolas como sustrato alternativo en cultivo sin suelo en tomate. *Actas de Horticultura*, 32: 327-332.

US Composting Council. (1997). Test methods for the examination of composting and compost (Interim Draft). US Composting Council, Bethesda, Maryland.

Villegas, F.J. (2004). Cultivo en fibra de coco II. In: Tratado de cultivo sin suelo, 3rd Ed., ed. M. Urrestarazu, Mundi-Prensa. Madrid, pp 650-667.

Warncke, D.D., (1986). Analyzing greenhouse growth media by the saturation extraction method. HortScience 21, 223-225.



Crop Production Technologies

Edited by Dr. Peeyush Sharma

ISBN 978-953-307-787-1
Hard cover, 276 pages
Publisher InTech
Published online 05, January, 2012
Published in print edition January, 2012

Crop production depends on the successful implementation of the soil, water, and nutrient management technologies. Food production by the year 2020 needs to be increased by 50 percent more than the present levels to satisfy the needs of around 8 billion people. Much of the increase would have to come from intensification of agricultural production. Importance of wise usage of water, nutrient management, and tillage in the agricultural sector for sustaining agricultural growth and slowing down environmental degradation calls for urgent attention of researchers, planners, and policy makers. Crop models enable researchers to promptly speculate on the long-term consequences of changes in agricultural practices. In addition, cropping systems, under different conditions, are making it possible to identify the adaptations required to respond to changes. This book adopts an interdisciplinary approach and contributes to this new vision. Leading authors analyze topics related to crop production technologies. The efforts have been made to keep the language as simple as possible, keeping in mind the readers of different language origins. The emphasis has been on general descriptions and principles of each topic, technical details, original research work, and modeling aspects. However, the comprehensive journal references in each area should enable the reader to pursue further studies of special interest. The subject has been presented through fifteen chapters to clearly specify different topics for convenience of the readers.